

**APPARATUS AND METHOD FOR AN ACTIVE POWER-ON RESET
CURRENT COMPARATOR CIRCUIT**

Field of the Invention

5 The present invention relates to the field of power-on reset circuits, and in particular, to an apparatus and method for an active power-on reset current comparator circuit.

Background of the Invention

10 Circuits often use a power-on reset (POR) signal for resetting the circuitry during power-up. As the bias current approaches a stable operating level, the POR signal is used to reset, or initialize, the circuitry. Circuits may also use a POR signal to disable certain circuits until a stable bias current signal is available. Using a POR signal ensures stable operation of the circuit until a steady-state is reached.

Brief Description of the Drawings

15 FIGURE 1 illustrates a schematic diagram of an active power-on reset current comparator circuit;

 FIGURE 2 illustrates a schematic diagram of another active power-on reset current comparator circuit; and

20 FIGURE 3 illustrates a schematic diagram of a further active power-on reset current comparator circuit, in accordance with the present invention.

Detailed Description of the Preferred Embodiment

 In the following detailed description of exemplary embodiments of the invention, reference is made to the accompanied drawings, which form a part hereof, and which is shown by way of illustration, specific exemplary embodiments of which
25 the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that other embodiments may be utilized, and other changes may be made, without departing

from the spirit or scope of the present invention. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the present invention is defined only by the appended claims.

Throughout the specification, and in the claims, the term "connected" means a direct electrical connection between the things that are connected, without any intermediary devices. The term "coupled" means either a direct electrical connection between the things that are connected, or an indirect connection through one or more passive or active intermediary devices. The term "circuit" means one or more passive and/or active components that are arranged to cooperate with one another to provide a desired function. The term "signal" means at least one current signal, voltage signal or data signal.

The present invention relates to an active power-on reset (POR) current comparator circuit. The POR current comparator circuit compares the ratio of two currents. A first current is produced in response to a current proportional-to-absolute-temperature generator (I_{PTAT} generator). The I_{PTAT} current is determined according to a first resistance level. A second current is determined in response to the I_{PTAT} current and a second resistance level. When compared, the first and second currents are related according to a scaling factor (e.g., N). The scaling factor may be selected such that the POR signal will de-assert at any selected point during startup. The present invention allows for the generation of a POR signal from a higher voltage supply (e.g., 40V) while using a minimum number of components. In previous applications, standard comparator circuits were used, but required additional circuitry to prevent breakdown at higher voltages.

FIGURE 1 illustrates a schematic diagram of an active power-on reset (POR) current comparator circuit. The POR current comparator circuit (100) includes start-up circuit 110, I_{PTAT} generator 112, comparator stage 114, and gain stage 130. I_{PTAT} generator 112 (i.e., current generator 112) includes current mirror circuit 120, transistors Q1 and Q2, and resistance circuit R_1 . Comparator stage 114 includes current mirror circuit 122, transistors Q3 and Q4, and resistance circuit $N \cdot R_1$. Current mirror

circuit 120 includes transistors M1 and M2. Current mirror circuit 122 includes transistors M3 and M4.

Transistor M1 includes a source that is coupled to an upper voltage supply (Vdd), a gate that is coupled to node N1, and a drain that is coupled to node N2.

5 Transistor M2 includes a source that is coupled to Vdd and a gate and drain that are coupled to node N1. Transistor M3 includes a source that is coupled to Vdd and a gate and drain that are coupled to node N5. Transistor M4 includes a source that is coupled to Vdd, a gate that is coupled to node N5, and a drain that is coupled to node N7. Transistor Q1 includes an emitter that is coupled to a lower voltage supply (Vss) and a

10 base and collector that are coupled to node N2. Transistor Q2 includes an emitter that is coupled to node N3, a collector that is coupled to node N1, and base that is coupled to node N2. Transistor Q3 includes an emitter that is coupled to node N4, a collector that is coupled to node N5, and a base that is coupled to node N2. Transistor Q4 includes an emitter that is coupled to Vss, a collector that is coupled to node N7, and a base that is

15 coupled to node N2. Resistance circuit R₁ is coupled between node N3 and Vss. Resistance circuit N·R₁ is coupled between node N4 and Vss. Start-up circuit 110 is coupled between node N1 and Vss. Gain stage 130 is coupled between node N7 and the output (POR).

In operation, the POR current comparator circuit (100) produces a POR

20 signal for use in resetting logic devices and mask reference startup signals during the initial power supply ramp of an integrated circuit. Actuation of the POR signal is dependent on the ratios between the currents flowing through the resistance circuits R₁ and N·R₁ (where N is a scaling factor). The current (I_{PTAT1}) flowing through resistance circuit R₁ may be determined at steady state according to the following voltage loop

25 equations:

$$-V_{be1} + V_{be2} + I_{PTAT1}R_1 = 0 \quad (1)$$

$$V_{be} = V_t \ln(I_c / I_s) \quad (2)$$

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$$-V_t \ln(I_{PTAT1} / I_s) + V_t \ln(I_{PTAT1} / AI_s) = -I_{PTAT1} R_1 \quad (3)$$

$$I_{PTAT1} = \frac{V_t \ln(A)}{R_1} \quad (4)$$

wherein V_{be} corresponds to the base-emitter voltage of the corresponding transistor, V_t corresponds to the threshold voltage, and A corresponds to the ratio between emitter areas for transistors Q1 and Q2 ($Q2 / Q1$).

Correspondingly, the current (I_{PTAT2}) flowing through resistance circuit $N \cdot R_1$ may be expressed as follows:

$$I_{PTAT2} = \frac{V_t \ln(A)}{N \cdot R_1} \quad (5)$$

By scaling N to be larger than 1, the POR signal actuates when the current flowing through resistance circuit $N \cdot R_1$ is at approximately the level expressed in the following equation:

$$I_{PTAT2} = I_{PTAT1} \left(\frac{1}{N} \right) \quad (6)$$

As presented in the preceding equation, the scaling factor (N) may be selected such that the POR signal is actuated at a selectable point (i.e., time interval or supply voltage level) during startup.

As voltage increases on V_{dd} , start-up circuit 110 continues to hold the gate voltages for transistors M1 and M2 at a low level. Once a selected voltage on V_{dd} is reached, start-up circuit 110 releases the gate voltages for transistors M1 and M2, activating I_{PTAT} generator 112. As start-up circuit 110 disengages, low level currents are flowing throughout the entire circuit (100), while competing currents will be flowing through transistors M4 and Q4. Initially, the current (I_{PTAT2}) through transistor Q3 and resistance circuit $N \cdot R_1$ is measurably higher than the current flowing through Q4. In one example, the emitter area for transistor Q1 corresponds to $1X$, transistor Q2 to AX , transistor Q3 to AX , and transistor Q4 to $1X$. The difference in emitter area

between transistor Q3 and transistor Q4, results in a V_{be} for transistor Q3 that is less than the V_{be} for transistor Q4. The lower V_{be} for transistor Q3 results in a small current (I_{PTAT2}) flowing through resistance circuit $N \cdot R_1$, which is larger than the corresponding current flow in transistor Q4. This current (I_{PTAT2}) is mirrored by current mirror 122, to
5 flow through transistor M4. Accordingly, the current through transistor M4 is also measurably higher than the current through transistor Q4, pulling the POR signal to a high logic level. As the current I_{PTAT2} begins to ramp up, the current through transistor Q4 increases. At a selected bias current level, the current flowing through transistor Q4 surpasses the current flowing through Q3 and M4, pulling the POR signal to a low logic
10 level. During a start-up cycle, the POR is initially pulled high, preventing instability of subsequent circuits (not shown), and then the POR circuit is pulled low, allowing subsequent circuitry to initiate at an acceptable bias current. The POR circuit remains low for the remainder of the operational range of the POR current comparator circuit (100).

15 In another embodiment, transistors Q3 and Q2 are not matched in size as described above. Instead, transistor Q3 may be made a 1X device, while proportionally reducing the size of resistance circuit $N \cdot R_1$ (e.g., by $1/A$) and transistor circuit Q4 (e.g., by $1/A$).

In yet another embodiment, a transistor (not shown) is included to source
20 more current into transistor Q4. When the POR signal is pulled to a low logic level, transistor Q4 saturates, resulting in base current injection back into I_{PTAT} generator 112. This injection of base current may result in errors of regulation for I_{PTAT} generator 112. An additional transistor sourcing more current into transistor Q4 prevents transistor Q4 from reaching saturation.

25 FIGURE 2 illustrates a schematic diagram of another active power-on reset (POR) current comparator circuit. The POR current comparator circuit (200) includes I_{PTAT} generator 212, comparator stage 214, cascode bias circuit 224, and gain stage 230. I_{PTAT} generator 212 includes current mirror circuit 220, transistors M9 and M10, and resistance circuit R_1 . Comparator stage 214 includes current mirror circuit
30 222, transistors M11 and M12, and resistance circuit $N \cdot R_1$. Current mirror circuit 220

includes transistors M1, M2, M3, and M4. Current mirror circuit 222 includes transistors M5, M6, M7, and M8. Gain stage 230 includes transistors Qx and Mx, and resistance circuit Rx.

Transistor M1 includes a source that is coupled to an upper voltage supply (Vdd), a gate that is coupled to node N1, and a drain that is coupled to node N2. Transistor M2 includes a source that is coupled to Vdd and a gate and drain that are coupled to node N1. Transistor M3 includes a source that is coupled to node N2, a gate that is coupled to node N3, and drain that is coupled to node N5. Transistor M4 includes a source that is coupled to node N1, a gate that is coupled to node N3, and a drain that is coupled to node N4. Transistor M5 includes a source that is coupled to Vdd and a gate and drain that are coupled to node N7. Transistor M6 includes a source that is coupled to Vdd, a gate that is coupled to node N7, and a drain that is coupled to node N8. Transistor M7 includes a source that is coupled to node N7, a gate that is coupled to node N9, and drain that is coupled to node N10. Transistor M8 includes a source that is coupled to node N8, a gate that is coupled to node N9, and a drain that is coupled to node N12. Transistor M9 includes a source that is coupled to a lower voltage supply (Vss) and a drain and gate that are coupled to node N5. Transistor M10 includes a source that is coupled to node N6, a drain that is coupled to node N4, and gate that is coupled to node N5. Transistor M11 includes a source that is coupled to node N11, a drain that is coupled to node N10, and a gate that is coupled to node N5. Transistor M12 includes a source that is coupled to Vss, a drain that is coupled to node N12, and a gate that is coupled to node N5. Resistance circuit R₁ is coupled between node N6 and Vss. Resistance circuit N·R₁ is coupled between node N11 and Vss. Cascode bias circuit 224 is coupled between node N3 and node N9.

In gain stage 230, transistor Qx includes a base and collector that are coupled to node N12, and an emitter that is coupled to node N13. Transistor Mx includes a source that is coupled to node N13, a gate that is coupled to node N12, and a drain that is coupled to node N14. Resistance circuit Rx is couple between node N14 and Vss.

In operation, POR current comparator circuit 200 operates similarly to POR current comparator circuit 100 shown in FIGURE 1. In the present embodiment, the BJT transistors (Q1-Q4) shown in FIGURE 1 have been replaced by sub-threshold FET transistors (M9-M12). In addition, different current mirrors (220, 222) are used in place of the current mirrors (120, 122) shown in FIGURE 1. Current mirrors 220 and 222 are cascoded current mirrors that utilize an external cascode bias circuit (224). Also, gain stage 230 illustrates an exemplary gain stage for use with the present invention. In other embodiments, other gain stages may be utilized (e.g., the gain stage shown in FIGURE 3), or the gain stage may be eliminated from the circuit.

Gain stage 230 includes a diode connected NPN transistor (Q_x), a PMOS device (M_x), and a resistance circuit (R_x) to provide an inverting gain stage for the output of the POR signal. Transistor Q_x is used to protect transistor M_x from an over-voltage that may occur at the voltage supply (V_{dd}). If an over-voltage condition does occur, transistor Q_x prevents the gate of transistor M_x from increasing too high. In other embodiments, resistance circuit R_x may be replaced with a current source or diode connected circuit.

FIGURE 3 illustrates a schematic diagram of a further active power-on reset (POR) current comparator circuit, in accordance with the present invention. The POR current comparator circuit (300) includes I_{PTAT} generator 312, comparator stage 314, and gain stage 230. I_{PTAT} generator 312 includes current mirror circuit 320, transistors Q1 and Q2, and resistance circuit R₁. Comparator stage 314 includes current mirror circuit 322, transistors Q3 and Q4, and resistance circuit N·R₁. Current mirror circuit 320 includes transistors M1, M2, M3, and M4. Current mirror circuit 322 includes transistors M5, M6, M7, and M8. Gain stage 330 includes inverter circuits INV1 and INV2.

Transistor M1 includes a source that is coupled to a lower voltage supply (V_{ss}), a gate that is coupled to node N1, and a drain that is coupled to node N2. Transistor M2 includes a source that is coupled to V_{ss} and a gate and drain that are coupled to node N1. Transistor M3 includes a drain and gate that are coupled to node N2, and a source that is coupled to node N4. Transistor M4 includes a drain that is

coupled to node N1, a gate that is coupled to node N2, and a source that is coupled to node N3. Transistor M5 includes a source that is coupled to Vss, and a gate and drain that are coupled to node N6. Transistor M6 includes a source that is coupled to Vss, a gate that is coupled to node N6, and a drain that is coupled to node N7. Transistor M7 includes a drain that is coupled to node N6, a gate that is coupled to node N2, and source that is coupled to node N9. Transistor M8 includes a drain that is coupled to node N7, a gate that is coupled to node N2, and a source that is coupled to node N11. Transistor Q1 includes an emitter that is coupled to an upper voltage supply (Vdd) and a base and collector that are coupled to node N4. Transistor Q2 includes an emitter that is coupled to node N5, a collector that is coupled to node N3, and base that is coupled to node N4. Transistor Q3 includes an emitter that is coupled to node N10, a collector that is coupled to node N9, and a base that is coupled to node N4. Transistor Q4 includes an emitter that is coupled to Vss, a collector that is coupled to node N11, and a base that is coupled to node N4. Resistance circuit R₁ is coupled between node N5 and Vss. Resistance circuit N·R₁ is coupled between node N10 and Vss.

In gain stage 330, inverter circuit INV1 is coupled between node N11 and node N12. Inverter circuit INV2 is coupled between node N12 and the output (POR).

In operation, POR current comparator circuit 300 operates similarly to the POR current comparator circuits (100, 200) shown in FIGURES 1 and 2. In the present embodiment, the NPN BJT transistors (Q1-Q4) shown in FIGURE 1 have been replaced by PNP BJT transistors (Q1-Q4). In addition, different current mirrors (320, 322) are used in place of the current mirrors (120, 122) shown in FIGURE 1. Current mirrors 320 and 322 are self-biased cascoded current mirrors. Also, gain stage 330 illustrates another exemplary gain stage for use with the present invention. Gain stage 330 includes two inverter circuits INV1 and INV2. The inverter circuits (INV1, INV2) serve to clean up and provide gain to the POR signal. Two inverter circuits are illustrated, however, in other embodiments, any number of inverter circuits that provide the desired POR signal may be used.

In the above figures (1-3), the circuit is shown as including a lower supply voltage (V_{ss}). V_{ss} is interchangeable with a ground connection and should not be construed as a limitation of the invention. In addition, the start-up circuit (110) shown in FIGURE 1 may be used in FIGURE 2, FIGURE 3, and further embodiments without departing from the scope of the invention.

The above specification, examples and data provide a complete description of the manufacture, use, and composition of the invention. Since many embodiments of the invention can be made without departing from the spirit and scope of the invention, the invention resides in the claims hereinafter appended.

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